House Committee on Science and Technology
Subcommittee on Space and Aeronautics Hearing

"Keeping the Space Environment Safe for Civil and Commercial Users"

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Thank you, Madam Chairman, for providing an opportunity to discuss this important topic. The long-term "sustainability" of the space environment, from low Earth orbit and out to the Moon, is of fundamental importance to many national interests, from national security to the global economy.

<u>Introduction</u>
Space activities contribute to the long-term well being of society through improved scientific understanding in every field of knowledge, most notably with respect to the global environment. The design, development, and operation of space systems constitute major technical and managerial challenges in systems engineering and thus help strengthen the engineering capacities of participating nations. China and India are but the latest examples of nations that see the value of space to their further development.

Most immediately, space systems such as satellite communications, environmental monitoring, and global navigation satellite systems are crucial to the productivity of many types of national and international infrastructures such as air, sea, and highway transportation, oil and gas pipelines, financial networks, and global communications.

Information services enabled by the unique capabilities and global reach of space systems are crucial to the functioning of the global economy. In a time of global economic crisis, the United States and other space-faring nations need to cooperate more closely to protect space systems from intentional or unintentional interference.

The space environment today is a very different from what it was in 1957 when the first satellite was launched, or 1972 when the international convention on liability for damage caused by space objects was signed. In the past two years, a Chinese anti-satellite test and communications satellite collision have added thousands of orbital debris to the local space environment, much of which will be in orbit for many years to come. Today, the Joint Space Operations Center is tracking over 19,000 man-made objects and that number is growing.

The space environment is not safe – it might be fairly characterized as an environment in which everything is trying to kill you and your spacecraft. It can however be made sustainable in that the vital functions we use space for today can be reliably maintained for generations to come.

Concerns about sustainability arise not so much from the activities of traditional space faring nations, like the United States, but from new entrants such as Iran and possibly North Korea who have virtually no capabilities to monitor and control space objects. Concerns arise with respect to China, which has significant and impressive space capabilities, but whose ASAT test showed an alarming disregard or lack of understanding of orbital debris. Finally, there are non-state actors like universities, who are deploying increasingly small satellites for commercial and scientific purposes that may be challenging to monitor in the crowded near Earth environment.

<u>Space Sustainability</u>
The irreversible accumulation of orbital debris constitutes the most obvious concern for the sustainability of space use. However, it is not the only factor and I'd like to mention two that are often overlooked:

Space weather – yes, space has weather of a sort. There are geomagnetic storms from the Sun, varying energies from the Van Allen radiation belts around the Earth, ionosphere disturbances and scintillations, and geomagnetic induced currents. Coronal mass ejections from the Sun and their associated shock waves can compress the Earth's magnetosphere and induce geomagnetic storms with effects on Earth as well as local space.

Space weather cannot be controlled, but monitoring and prediction are becoming more important as humans go farther out into space and more of the global economy depends on the reliable functioning of space systems. Space weather monitoring is becoming less of a "science project" and more of an operational requirement alongside traditional weather monitoring systems in space.

Radio frequency interference – there is no point in going to space if you cannot communicate home. No nation "owns" the radio frequency spectrum but all nations depend on keeping it free from interference, whether intentional or unintentional. Space-based services are particularly vulnerable to interference because satellites in space cannot easily increase their transmitted power in the face of increased noise. Many space services are not traditional two-way communications, but include passive monitoring, active sensing, and one-way broadcasting. As a result, critical frequency bands require special international protection, e.g., those used for GPS, weather and climate monitoring, and satellite communications.

There is growing pressure on all these bands from terrestrial commercial technologies and regulatory protections are more important than ever. In this regard, the Federal Communications Commission, in partnership with the National Telecommunications and Information Agency has an important role in protecting the national security, public safety requirements, and scientific needs of federal agencies relying on space systems.

Returning to the topic of orbital debris, it is easy to understand the appeal of terms like "space traffic control." The drama of International Space Station astronauts taking temporary refuge in their Soyuz return capsule and greater awareness of space operators taking precautionary maneuvers seem to argue for putting someone in charge. Unfortunately, "space traffic management" can be misleading on both technical and political grounds. The space environment is not like that of aviation or highways in that satellites cannot maneuver easily. Further, the space environment belongs to no one and thus there is no central authority that spacecraft owner/operators can use to protect regions of space vital to them. An international agreement authorizing an independent organization to provide and enforce where sovereign space assets may travels is a difficult concept for many nations.

Where the analogy with traffic management does work is in the idea of having a common understanding of definitions, standards, operating procedures, and practices for space operators to communicate with each other. As with international civil aviation, I am hopeful that they will communicate in English. Rather than imposing a "top down" space authority, there are promising avenues for an evolving consensus on "rules of the road" and confidence-building measures based on international norms for all types of space activity.

<u>Guidelines and Standards</u>
A good example of evolving international norms can be found in the Inter-Agency Space Debris Coordination Committee (IADC) guidelines on minimizing orbital debris. These guidelines deal with the break-up of space systems, end-of-mission-life satellite disposal, and avoiding intentional harm. Another good example is the international condemnation of the Chinese ASAT test that showed international awareness of the risks posed by tests that create long-lived orbital debris.

To support these norms and other national interests, there is a clear need for better space situational awareness for all space sectors – civil, commercial, and national security. While space traffic control may not be feasible, better space traffic monitoring is feasible. A first step in improved monitoring is to enable better, faster, standardized information exchanges among satellite owners and operators. Some good news here is that international, open standards are close to approval. The Consultative Committee for Space Data Standards (CCSDS) approved a Draft Recommended Standard for Orbit Data Messages in July of last year. The CCSDS is an international body of all major space agencies and over 400 space missions have chosen to use CCSDS communication standards. These missions have included everything from the U.S. rovers on Mars to the Chinese Chang'e missions to the Moon.

Use of CCSDS standards allows for (but does not mandate) operational cross-support among space agencies. Representation is quite broad, with expert participation from the French space agency (CNES), the European Space Operations Center (ESOC), the German Space Operations Center (GSOC), the Japanese space agency (JAXA), Intelsat, Inmarsat, the U.S. Air Force, and NASA's Goddard Spaceflight Center, and the Jet Propulsion Laboratory. Representation is not systematic, however, and often depends on a few dedicated individuals whose work is tolerated but not always supported by home institutions busy with other priorities. A more intentional U.S. strategy that resources and staffs international standards work would improve the coordination of U.S. positions and the chances for greater international support of those positions. For example, I would see closer coordination by the Air Force Space Command, National Reconnaissance Office, and the Operationally Responsive Space Office with on-going NASA efforts as a good near-term opportunity.

An important characteristic of CCSDS standards are that they are open and transparent and do not require the transfer of sensitive technologies. This is necessary if international satellite operators are to be able to share location data with each other – if not the characteristics of the satellites themselves. A more difficult challenge for space traffic monitoring will be in determining where a spacecraft might have been or where it will be. This requires mathematical modeling techniques of propagation or interpolation from existing information to make predictions. These models can vary quite a bit and will often contain proprietary techniques that make it difficult to make comparisons between different models. While models can and should evolve, it will be important to international acceptance that any proposed standard for a predictive model not be proprietary but subject to open inspection and improvement.

As satellite architectures evolve, information exchanges and practices can be expected to evolve as well. For example, it is difficult to track objects smaller than 10 centimeters in Earth orbit but networks of nano-satellites may be that small or smaller. Each such satellite or group of cooperative nano-satellites might be modeled as sphere of fixed size. Independent verification of their location might in turn require active measures such as transponder beacons or passive ones such as laser reflectors. Larger satellites could be used to carry piggyback payloads that observe their local environment and supplement information from dedicated ground and space-based sensors.

Different areas of space are used for different kinds of satellites and operational practices in low Earth orbit, geosynchronous orbit, and polar/sun-synchronous orbits will be different. Groups of communications satellites operated by the same owner in geosynchronous orbit tend to be relatively slow moving with respect to each other and can be spaced closely. Conversely, communications satellites operated by different owners in low Earth orbit may be moving at high speeds relative to each other and will need wider spacing for safety. In analogy to air traffic, satellites may be stacked into different altitudes and inclinations to ensure separation; with separations being wider for satellites operated non-cooperatives (i.e., by different organizations).

The IADC guidelines on orbital debris emerged from discussions of best practices among technical experts rather than legal arguments among international lawyers. Those technical discussions included government, academic, and commercial experts from many countries with a focus on what made operational sense. At this stage, it seems premature to specify any binding “rules of the road” for space but it is time to look at real-world operations and see if there are useful practices that could be documented in similar voluntary guidelines. The former head of the French space agency, Gerard Brachet, is currently leading international discussions along this line that have included the United States and other major space powers.

<u>Improving Data Sharing</u>

At congressional direction, the Air Force operates a Commercial and Foreign Entities Support program that distributes satellite positions (know as two-line elements) and related messages free of charge. This has been a good start toward improved data sharing across the different space sectors, but only partly satisfactory. The two-line element (TLE) data is not the most precise and is sometimes out-of-date or otherwise incorrect. This leads to false alarms about potential conjunctions due to the broad error envelopes associate with TLE position predictions. Such alarms in turn consume more analytical resources in requests for more precise and timely data to resolve potential concerns.

The Air Force rightly gives top priority to human missions in space and national security functions. Unfortunately, they don’t have the resources to look at everything (e.g., a continuous catalog-on-catalog collision screening) and some risks will not be addressed until it’s too late. This is my understanding of what happened in the case of the recent Iridium-Cosmos collision in which it was only apparent what happened after the fact.

To meet the need for more analytical attention as well as data from optical sources, radar sources and satellite owner/operators, the commercial satellite industry has proposed data sharing through and international data clearinghouse. It is understandable that firms with billions of dollars of assets at risk in space would want to take steps to protect those investments. The primary challenges to implementing a data sharing warehouse are not technical or economic, but policy, notably how to balance commercial and security interests in the dissemination of data.

While a single, inclusive space situational awareness program, operated by the government or industry may seem to be the obvious answer the “one size fits all” approach will likely not work for multiple reasons.

- The government may not want to say where some satellites are or even if they exist
- The government may not want to reveal what its full capabilities are or its limitations

- There is concern about liability and timeliness for any data provided
- There is the normal competition for public resources
- There will still be an international need for independent verification

These are some of the obvious concerns that would arise in managing information about U.S. government, international, and private sector satellites in a single source.

Aside from security, there is often a concern that the United States bears and would continue to bear a disproportionate share of the international space situational awareness (SSA) burden since we have the most capabilities. That is true but I would also say that we also have a disproportionate share of the dependency on space and improved data sharing is in our national self-interest. International cooperation provides an opportunity to access SSA data (e.g., optical, radar) from geographically dispersed areas of the world that would be expensive for us to access and an opportunity to routinely get data from satellite owner/operators who have better data than routinely found in government systems, at least compared to what is published in TLE form. While building new radars is quite expensive, it might be possible to exploit radio astronomy telescopes, but at some displacement of science observing time. Thus, outreach should include the international scientific community as well as foreign government and commercial industry.

The United States is already participating in an expanding dialog with the European Union and the European Space Agency (ESA) on space situational awareness cooperation. In February, ESA hosted a technical meeting in Germany for U.S. and European technical experts to discuss standards for space object survey and tracking as well as cooperation in space weather monitoring. These discussions should not remain limited to Europe, of course, but should include U.S. friends and allies in other regions, such as Asia. As with other forms of security cooperation, sharing space situational awareness data will likely see expanding circles of trust – proceeding from the United Kingdom, Australia, and Canada, to NATO members, Japan and then other space-faring states, such as India.

As part of expanding cooperation, more formal steps could be envisioned such as banning any destructive testing in space that would create long-lived orbital debris --- the kind of debris that pose a threat to all space activities. This would not necessarily means a ban on "space weapons" which would be unverifiable, nor would it ban space-based kinetic energy interceptors used for ballistic missile defense, or ground-based interceptors such as the SM-3. Priority should be placed on potential agreements that offer the best chance for an international consensus and verification.

Building international consensus can be a slow process but it should be kept in mind that there are risks in trying to be too comprehensive in approaches to space (e.g., creating a new treaty regime). There is a broad and flexible body of existing international space law that is sufficient for virtually anything we want to do in space. The development of new norms should start with our friends and allies that are active in space – in short, those with the most "skin in the game" and those willing to contribute new data sources or other capabilities.

Improving international space situational awareness is very feasible, in part because the information needed is quite basic and need not infringe on national security. The fundamental needs are to know where and when an object is located in space, a point of contact responsible for the object, plus knowledge of space weather and the Earth's atmosphere over time. There are many complex products and services that can be created with such basic information and space agencies and operators will do so. International cooperation should focus on sharing basic information using open standards while recognizing that proprietary "value-added" products will arise on their own in response to user needs.

Governance

It is an open question how international sharing of SSA data will occur. Several analogies come to mind in terms of governance models for international SSA data sharing. For example, sharing could evolve like the Internet, with a network growing based on common protocols. The CCSDS standards and rules of the road growing out of the IADC guidelines provide a starting point for this approach. A non-governmental, international, non-profit body modeled after ICANN (Internet Corporation for Assigned Names and Numbers) could encompass governments, non-governmental organizations, and private corporations that own and operate satellites to promote safer operations.

Another approach would be to expand the current Commercial and Foreign Entities (CFE) program by making high precision data more easily available for all reported objects. Sharing might initially be with other countries with security ties or space monitoring capabilities, similar perhaps to the U.S./Canadian sharing of warning information in NORAD, but on a much wider scale.

If expanded sharing via governments proves too slow, one might expect that geosynchronous (GEO) satellite operators (e.g., Intelsat, SES, J-Sat) will create their own data clearinghouse as a separate initiative. They would continue to use CFE-provided data but would share higher precision information from their satellites with other members.

It is hard to imagine the creation of a central international organization for SSA – what is sometimes called an "ICAO for Space" in analogy to the International Civil Aviation Organization. Similarly, it is hard to imagine expanding the role of the International Telecommunications Union (ITU) to include orbital debris. Both organizations have regulatory functions that work through sovereign states. They do not have direct operational roles. In the case of the ITU, it already has enough difficulties with managing the allocation of geosynchronous orbital slots due to the number of "paper satellites" in the pipeline already.

There are examples of mixing public and private data for common purposes, such as with weather predictions based on all sorts of international data. There are also examples where the government encourages non-government data sources, such as the International GNSS Service at the Jet Propulsion Laboratory that monitors the GPS constellation through a voluntary federation of over 200 sites around the world. However, there is a clear line between awareness of data from open sources and using that data to operate the GPS constellation. In the case of space situational awareness, the benefits of sharing information have to be balanced against the risk of that same information being used to harm U.S. or allied assets.
Another important policy question will be that of direct or indirect user fees. In general, international cooperation for the United States has worked best when not based on the exchange of funds, but the shared contributions to a common goal. The United States has opposed the charging of direct user fees for safety services in ICAO in order to not deter the use of those services. One might imagine similar treatment of orbital debris data as a safety service. While this might place a burden on the U.S. as the majority supplier of such data, our interests would not likely be served by trying to impose direct user charges that would lead to even more complex negotiations.

Summary

The issues that need to be addressed in keeping the space environment safe for civil and commercial users include:

1. **Protection of the space environment and mitigation of orbital debris**. Improving space situational awareness and reduction of the hazards posed by man-made orbital debris are both vital to the long-term sustainable use of space for all nations. Space-faring nations should adhere to consensus orbital debris mitigation standard practices recognized by the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space. Improving space situational awareness should also be regarded as a promising area of international cooperation. In this context, proposals for voluntary “rules of the road” for space traffic need to be seriously considered.

2. **Protection of the radio spectrum used by space services from harmful interference**, with special attention to aviation safety services such as GPS and environmental services such as remote sensing. After space launch, communication is the most pervasive requirement for all space systems. Space-faring nations should work through the Space Frequency Coordination Group and within the International Telecommunications Union to achieve international support for necessary protections. Space agencies and industries should closely track the standards development work of terrestrial data communications standardization bodies in order to ensure compatibility of emerging commercial devices and services with current and future space needs.

3. **Promotion of open, interoperable standards for space systems** and their associated mission operations systems to increase opportunities for international

collaboration in space. Space-faring nations should support space standards developed by the International Standards Organization and utilize the Consultative Committee for Space Data Systems and the Interagency Operations Advisory Group to strengthen capabilities for cross support across the international space community.

The core SSA policy problems are centered on data policy and information dissemination, followed by the assignment of appropriate roles and responsibilities to federal agencies and services. The primary data issue is to determine how much high precision information from U.S. government sources can be made available in a timely manner and with whom. The second issue is how to most effectively promote international acceptance of CCSDS-developed standards for multilateral data exchange and to encourage non-proprietary propagation and interpolation models for conjunction analyses.

The United States should recognize the value of space sustainability as an international public good that also supports its own strategic interests. The United States needs to retain freedom of action in space while at the same time recognizing the presence of new actors in space and our own dependence on space systems. The most promising approach toward international norms aligned with our interests is to engage with other parties in creating a technically based consensus on reducing the hazards posed by orbital debris. We should avoid top-down prescriptive, legalistic or politically driven structures that do not allow for flexible evolution. Similarly, we should remain focused on mutual protection against common hazards found in the space environment and not be tempted to overreach, e.g., the creation of comprehensive space weapons bans or centralized space traffic management authorities.

If we actively support open technical standards and operational innovations based on real-world benefits, we will have the credibility necessary to establish new international norms that will add to our security and strengthen our economy.

If we focus on continuing to earn the trust of the billions of users worldwide that today rely on space systems, we will have the international support necessary to sustain the use of space for generations to come.

Thanks you for your attention. I would be happy to answer any questions you might have.

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Dr. Pace received the NASA Outstanding Leadership Medal in 2008, the U.S. Department of State's Group Superior Honor Award, *GPS Interagency Team*, in 2005, and the NASA Group Achievement Award, *Columbia Accident Rapid Reaction Team*, in 2004. He has been a member of the U.S. Delegation to the World Radiocommunication Conferences in 1997, 2000, 2003, and 2007. He is a past member of the Earth Studies Committee, Space Studies Board, National Research Council and the Commercial Activities Subcommittee of the NASA Advisory Council. Dr. Pace is a currently a member of the Board of Trustees, University Space Research Association.